SURFACE MITIGATION

RESHAPING HIGHWALLS AND ROADS

DESCRIPTION

Highwalls of surface mines and roads are reshaped by backfilling or reduction. See Fig. 11.

Backfilling is generally applicable to surface coal mines, and involves the placement of fill material against the highwall until the wall is covered. Commonly, backfill consists of mine wastes, although at some sites conditions may require importation of fill material. Where necessary, surface and subsurface drainages are restored simultaneously with the backfill.

Highwall reduction is generally applicable to quarries, and involves the mitigation of visual scars and safety hazards. Where natural terrain is irregular, quarries leave long uniform benches. In addition, vegetation is sparse and contrasts with the surrounding area. The high walls can be reduced with blasting and earthmoving. Alternatively, the long continuous lines may be broken up with selective backfilling and blasting, construction of discontinuous benches, and rock sculpting.

Advantages: Backfilling enables complete environmental remediation. Highwall reduction can be effective under suitable conditions.

Disadvantages: Backfilling is costly. Highwall reduction does not restore original environment.

Cost: $0.40 to $1.50 per cu yd.

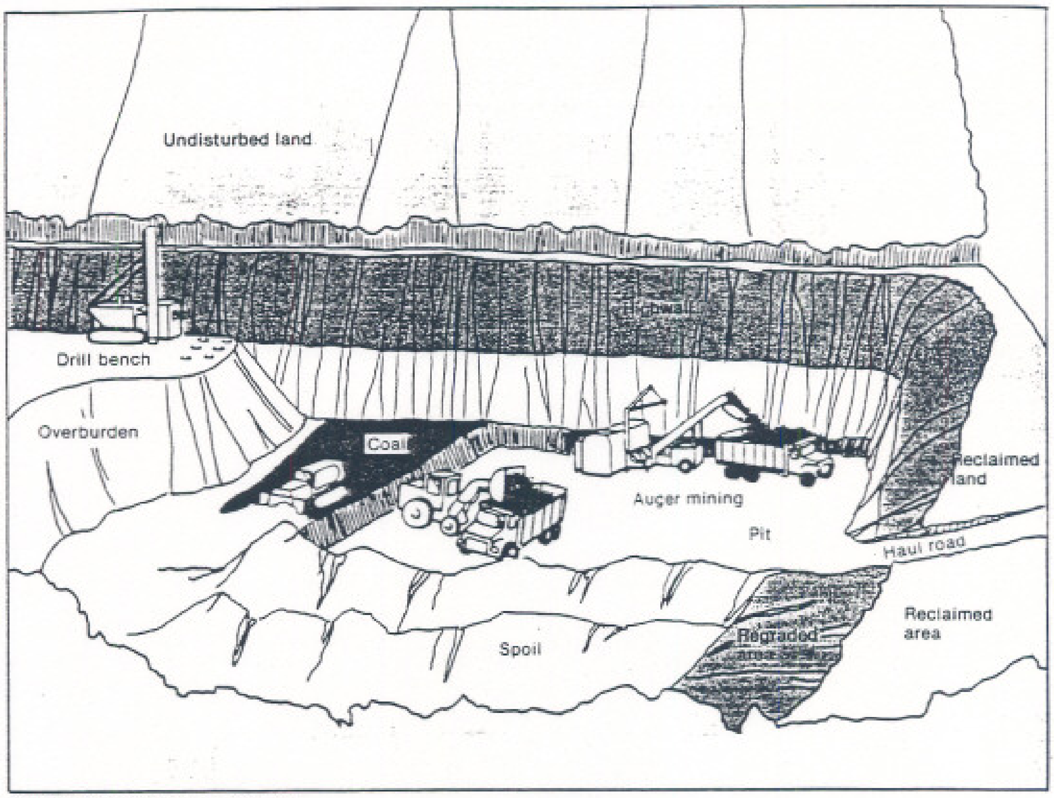
SITE CHARACTERIZATION

Locate and rank soil as suitable or unsuitable for salvage and use according to chemical or physical criteria that affect revegetation success.

Locate and rank backfill (overburden, mine waste rock, mine processing wastes) as suitable or unsuitable, the goal being a backfill that does not affect groundwater, the root zone, soil development, and plant growth. When mitigating a mine with toxic material, plan to monitor the site for 10 yr after successful establishment of vegetal cover.

Perform geomorhpologic analysis of drainage including sediment transport and deposition, runoff volumes, and peak flows.

For additional information, refer to the section on Site Characterization and Monitoring.



SOURCE: Office of Technology Assessment.

Figure 11a. Typical Highwall Operation
(Thorne, 1987, p. 31)

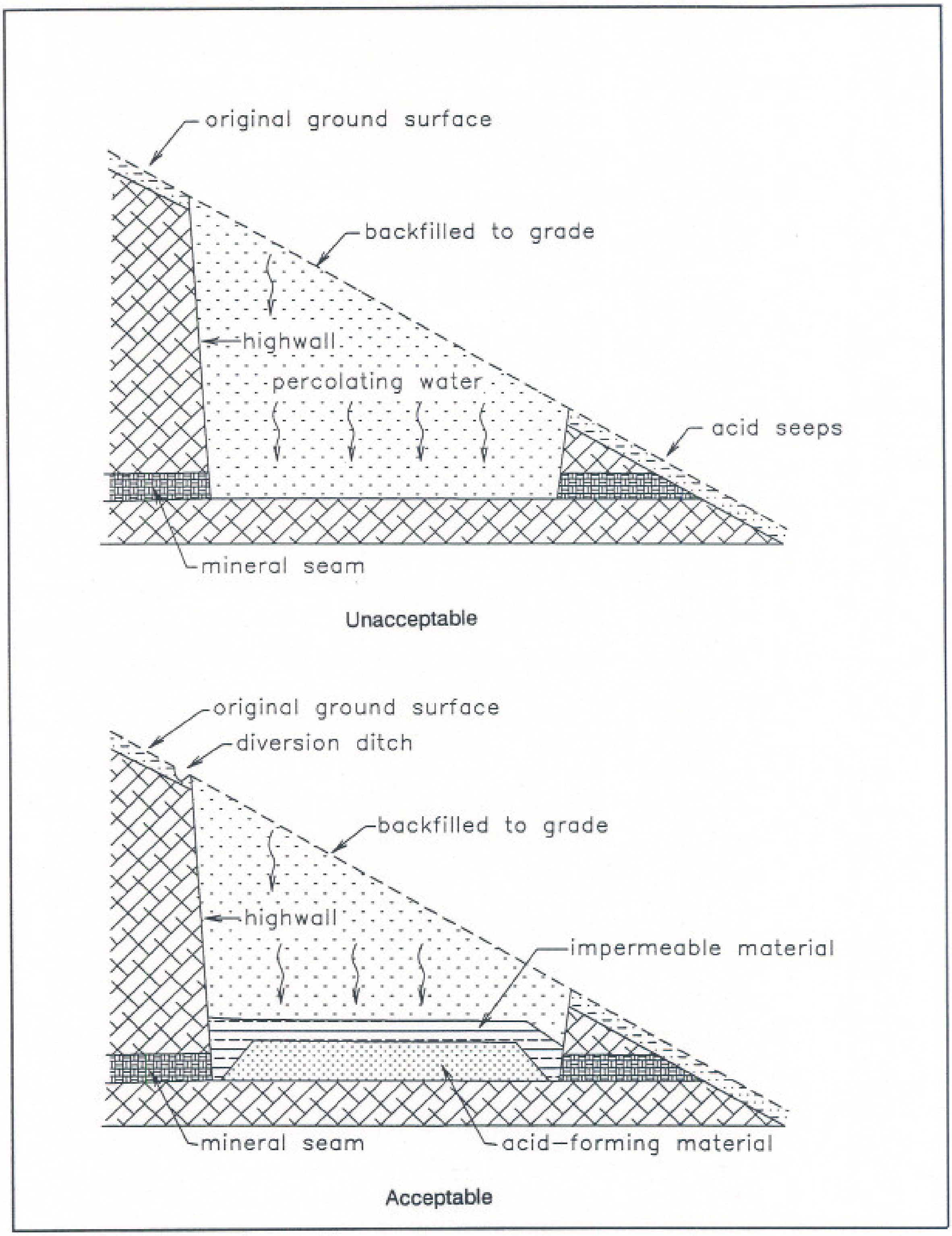


Figure 11b. Recontouring Highwalls
(Thorne, 1987, p. 31)

SOIL HANDLING

Salvage soil and stockpile until needed for revegetation. Protect stockpile from erosion with flat slopes, surface drainage control, and vegetation cover. Keep in mind that soils stockpiled for more than 2 to 4 yr deteriorate biologically due to decreases in the viability of seeds, roots, and microbiota.

If possible, handle soil in two lifts. Segregate topsoil (A and B horizons) from subsoil (C horizon), and then redress disturbed areas with the topsoil over the subsoil.

Refer to discussion of topsoil under Erosion and Sedimentation Control. Comply with Federal and State regulations on handling topsoil.

EROSION AND SEDIMENTATION CONTROL

Water discharge from disturbed areas may increase total suspended and dissolved solids. Provide a stable landscape that is not subject to excessive erosion or deposition:

* During construction activities, divert upland runoff around operations.

* Below disturbed areas, leave natural barriers or undisturbed strips of vegetation to filter runoff. See Fig. 12. In addition, place interceptor ditches, contain and treat water as described under Erosion and Sedimentation Control.

* After remediation is complete and vegetation reestablished, ditches and other drainage control structures should be graded over and planted.

Refer to section on Erosion and Sedimentation Control for additional information, and get help from the local office of Soil Conservation Service.

BACKFILLING GUIDELINES

Backfill methods vary widely among modern surface mines depending on the physical and chemical characteristics of the soil, overburden, and configuration of the mine. Medium to large backfill projects will usually require detailed design studies involving earthmoving, drainage, landscaping, and revegetation. The following discussion provides a broad outline of the requirements for backfilling.

Available backfill on a particular site usually has both deleterious and benign zones.

* Where some or all of the backfill has deleterious qualities, ensure that the backfill plan stipulates a

minimum (4 to 8 ft*) top layer of suitable material. Otherwise isolate the unsuitable material with an impermeable barrier or treat, as described in the boxes. See Fig. 11b.

* Top 4 ft of backfill should be free of boulders larger than a specified minimum (1 cu yd*) size.

* Backfill should be free of vegetation which in time will decompose and cause slumping or minor subsidence.

<u>Burial of Deleterious Materials</u>

* For extremely toxic material, prepare clay seals or barriers to prevent water seepage that could contaminate surface or groundwater.

* Acidic material should be buried below natural water level, if possible. This will inhibit acid production if the water table does not fluctuate over the burial.

* Material must be buried as soon as possible to minimize toxic effluents.

* Compact toxic backfill, to minimize movement of water through the material.

<u>Treatment for Acidic Materials</u>

* Consider any soil or water pH of 4.5 or less to be strongly acid.

* The most common treatment is application of lime to increase pH.

* Collect samples from the material, and determine acid production. Each sample should weigh approximately 1 lb, excluding rock and gravel.

* Table VIII specifies the amounts of liming required to achieve a soil pH of 5.5 from various initial pH levels.

* When the liming rate exceeds 5 tons per acre, scarify upper layer of overburden. Apply lime in 2 to 3 passes, and work lime into upper 8 to 10 in. between passes with ripping or scarifying.

* Apply gypsum to treat salt problems caused by migration of chemical salts to the surface.

Treatment for Alkaline Materials

* Alkaline soils have a pH of 7 to 10 or greater, depending on salinity.

* There are three methods of treating alkaline soils:

  1. Leach out sodium and other salts by flooding with irrigation water. Flooding is primarily useful with high concentrations of calcium and magnesium. However, there is a risk flooding will increase sodium and OH ions.

  2. Skim off surface incrustations of accumulated salts by physical removal. Rarely successful in long term because the basic evaporation process is not changed and salts continue to accumulate.

  3. Chemically convert soils with gypsum, caustic alkali carbonates become sulfates. Scarify several tons per acre into soil and keep moist to hasten reaction.

TABLE VIII
LIMESTONE ($CaCO_3$) SOIL TREATMENT

pH Change in Plow Depth Layer	Liming Rate, lb/acre					
	Sand	Sandy Loam	Loam	Silt Loam	Clay Loam	Muck
4.0 to 6.5	2,600	5,000	7,000	8,400	10,000	19,000
4.5 to 6.5	2,200	4,200	5,800	7,000	8,400	16,200
5.0 to 6.5	1,800	3,400	4,600	5,6000	6,600	12,600
5.5 to 6.5	1,200	2,600	3,400	4,000	4,600	8,600
6.0 to 6.5	600	1,400	1,800	2,200	2,400	4,400

Neutralizing Value of Pure Limes

Material	Chemical	Neutralizing Value, %
Calcium Oxide	CaO	179
Calcium hydroxide	$Ca(OH)_2$	136
Dolomite	$CaMg(CO_3)_2$	109
Calcium carbonate	$CaCO_3$	100
Calcium silicate	$CaSiO_3$	86

REFERENCE: (CFA, 1980)

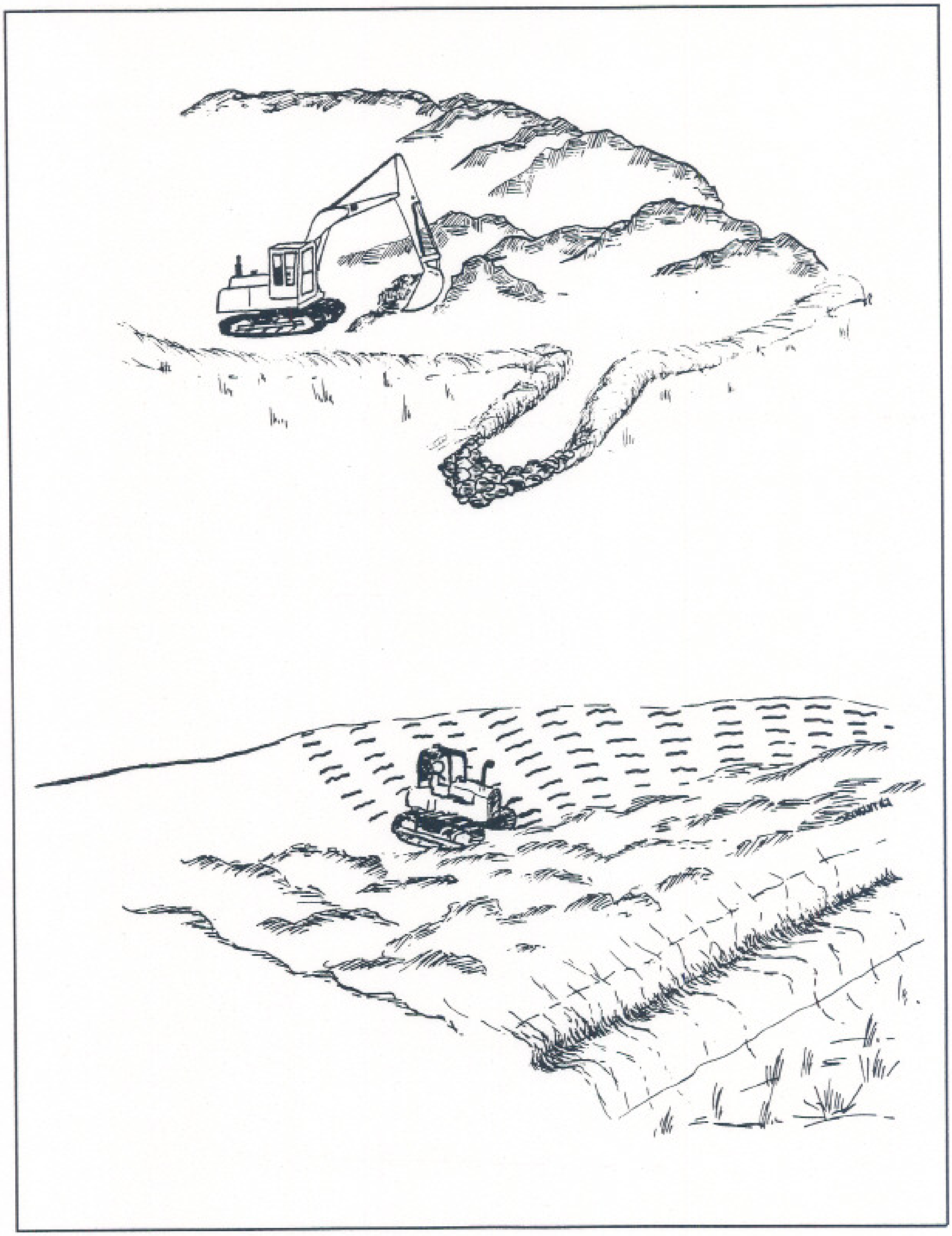


Figure 12. Sedimentation Barriers
(PDER, 1978, p. 62)

Backfill openings to the approximate original contour unless there is limited fill:

* The four basic hillslope profiles are uniform, concave, convex, and complex. See Fig. 13. Complex and concave profiles are the more stable landforms, and reshaping should approach these stable profiles.

* Subsurface drainage is often required to prevent subsidence of backfill and extreme gullying on steep hillslopes. See Fig. 14. This subsurface drainage consists of French drains that collect water, and sometimes slope-pipes that carry water to the toe of the hillslope.

* Specify maximum (3h:1v to 2.5h:1v*) hillslopes.

* Place backfill in layers and compact all but the top zone (4 ft to 8 ft*). (Fig. 15) Improper fill covers floor with rubble that can cause voids, confine groundwater, and create unstable ground.

* In top 8 ft, keep dozing and grading to a minimum. Excessive grading leads to compaction which greatly reduces water-infiltration and the survival of vegetation.

Design restored surface channels as described under Erosion and Sedimentation Control.

HIGHWALL REDUCTION GUIDELINES

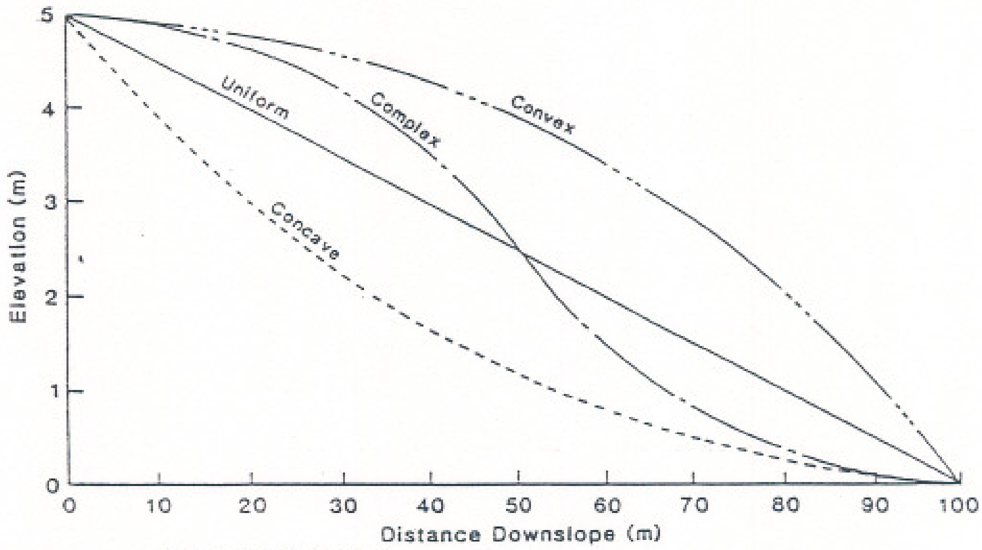
Mitigation of visual impact involves consideration of form, line, texture, and color. Selective blasting and/or backfilling, construction of discontinuous benches, and rock sculpting are illustrated in Fig. 16. Design landscaping, vegetation, and color that minimizes contrast between restored area and adjacent undisturbed area:

* Increase the number of benches by cutting down bench height and width. This reduction also enhances hillslope stability and revegetation.

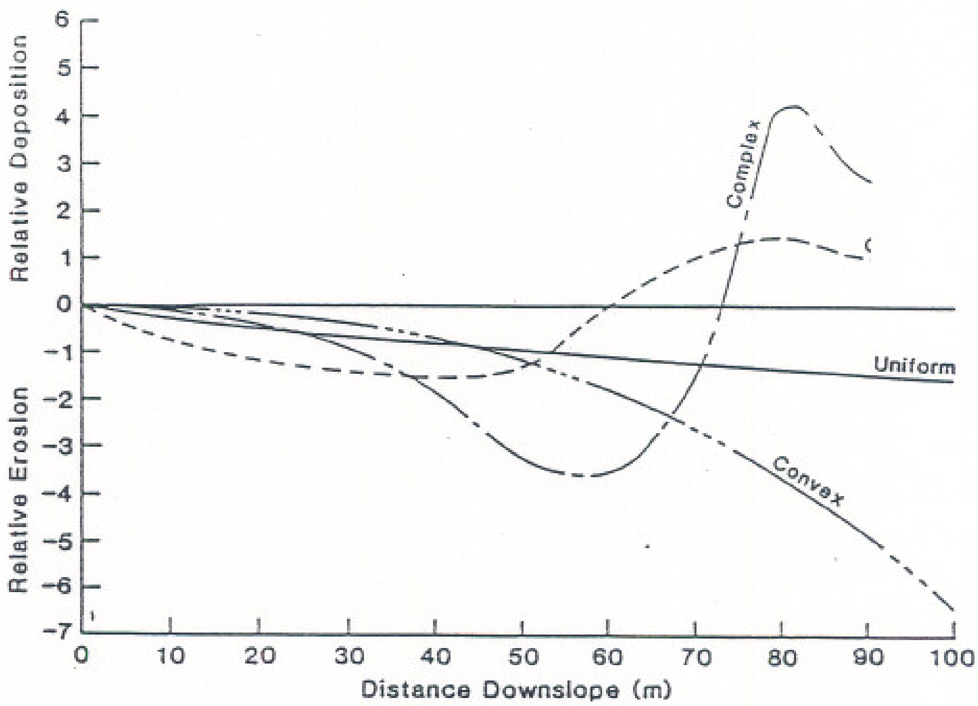
* Create transition hillslopes between undisturbed areas and the quarry. Drill blast holes progressively more shallow away from crest of the highwall. Blast and grade rock into transition hillslopes. In some cases, surface rock may be weathered, and the transition hillslope can be ripped and dozed without blasting.

* Selectively blast and backfill quarry benches.

* Slope stability engineering is required to insure that unstable ground is not created.



Slope Shapes



Relative Erosion and Deposition along Various Profile Shapes

Figure 13. Hillslope Profiles and Erosion
(Lidstone & Anderson, 1989, p. 480)

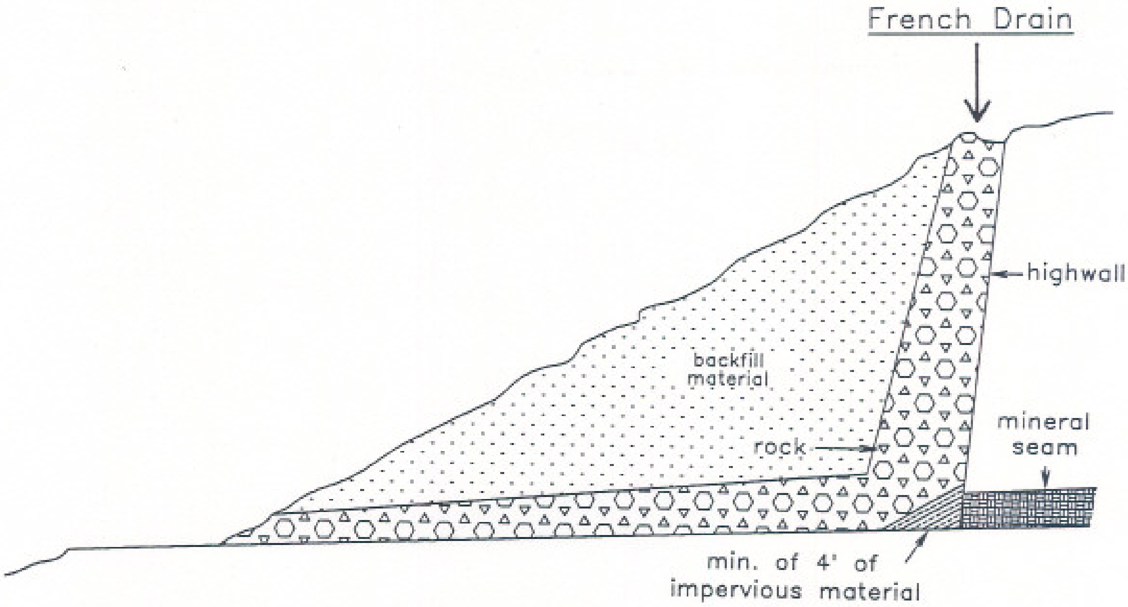


Figure 14. French Drains
(Thorne, 1987, p. 24)

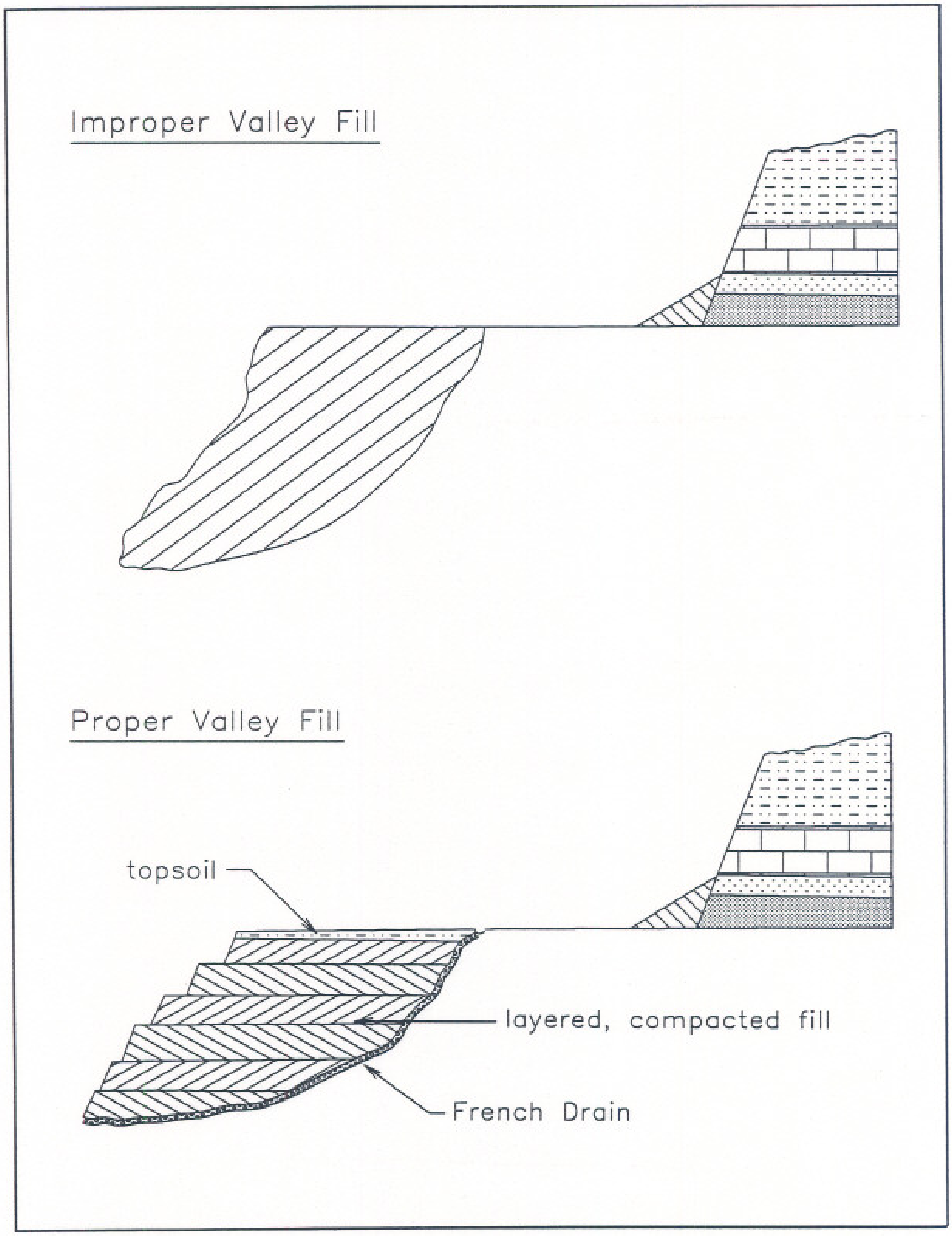
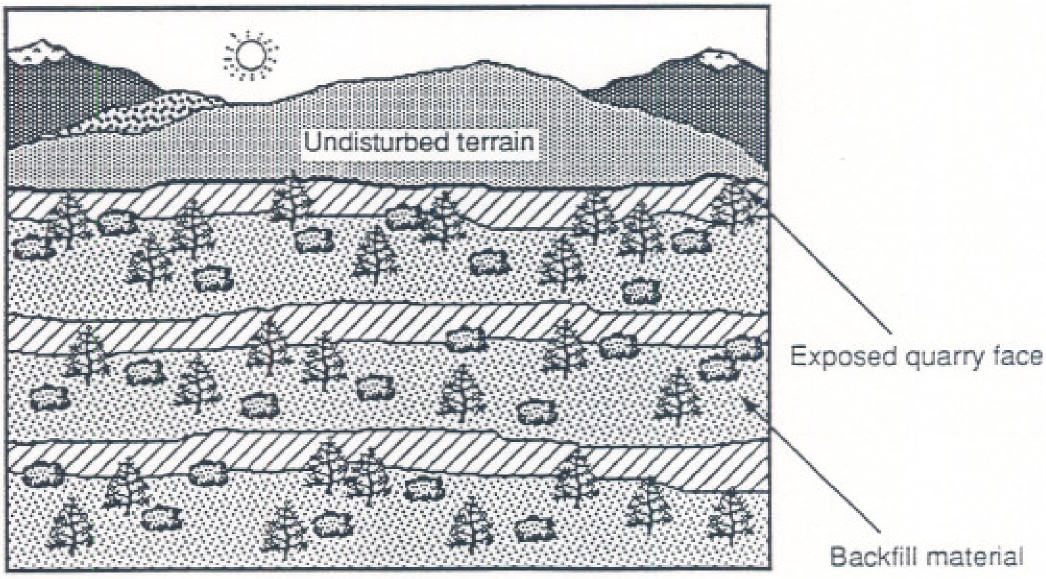
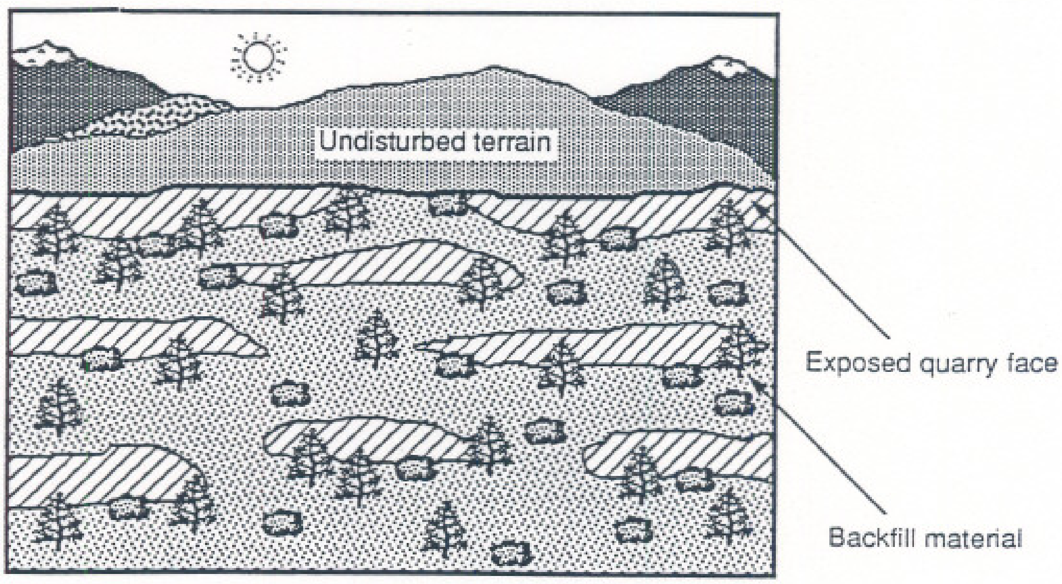


Figure 15. Proper Backfill
(Thorne, 1987, p. 28)



Partially Backfilled and Planted with Trees and Shrubs



Partially Backfilled and Planted with Trees and Shrubs

Figure 16. Continuous vs. Discontinuous Benches
(Banta, 1989, p. 39)

* Mining exposes fresh unweathered rock which may contrast with the surrounding area. Color blend the exposed rock with vegetation, barriers or berms, or rock staining.

In active quarries, minimize visual impact by disturbing only portions of the mining area, and then mitigating mined-out areas as mining progresses into new areas.

ROAD GUIDELINES

Mine roads often have the greatest impact of the various mining activities. See Fig. 17. Mitigate road disturbances as follows:

* Remove road surface and subbase. Gravel can be salvaged for other uses.

* Remove culverts.

* Rip on contour to reduced compaction.

* On hillslopes up to 40%, large bulldozers can restore original contours.

* Roads on hillslopes greater than 40% can be restored to or near original profile with large backhoes or draglines.

* Pull berm and outside shoulder up the cut slope as far as possible. Use backhoe or dragline.

REFERENCES: This section paraphrased from Banta et al, 1990, p. 38; PDER, 1978; Thorne, 1987, p. 25 -41; USOTA, 1986, p. 63; USFS, no date, p. 44.

WASTE DUMP STABILIZATION

DESCRIPTION

Mine waste dumps include abandoned stockpiles, overburden and spoil banks from surface mines, development rock from underground mines, mill tailings, and other processing wastes. Often dumps are unconsolidated, unstable, and their side slopes are at risk from ground slides or flows. Fugitive dust is a major environmental hazard associated with dry and barren dumps. Many tailings dams contain polluted water that leaks either into surface or groundwater. In addition, dump material is often toxic. Surface runoff and subsurface water add to instability and toxicity of dumps.

Figure 17. Road Impacts

only to become unstable and slide again. Flows occur where the dump becomes wet enough to take on fluid properties. Flow failures may be sudden, rapid, and once in motion, generate considerable momentum.

Cost: $0.40 to $1.50 per cu yd.

STABILIZATION TECHNIQUES

If the particular waste dump contains toxic material, it must be removed, and isolated or treated, as described under Reshaping Highwalls and Roads. Otherwise, the dumps are stabilized and then revegetated. Where there are risks to public safety and the environment, stabilization projects require the expertise of a qualified geotechnical engineer.

Do not breach any tailings or slimes dams unless the material has been thoroughly characterized, the material behind the dam removed, and the breach carefully engineered.

Generally, the long term factor of safety for stable fills equals 1.25 or more.

Stabilization techniques include removal, restraint, and drainage control. These techniques are usually used in combination along with the techniques described under Erosion and Sedimentation Control.

<u>Removal</u> involves total or partial excavation of the dump and placing the material in an engineered fill. Removal requires heavy earthmoving equipment.

<u>Restraint</u> places walls at the toe of unstable ground, and there are two basic types -- gravity and cantilever.

Gravity walls include cribs, gabions, berms, and reinforced earth walls. Gravity walls are able to withstand settlement without major damage to their structural integrity.

Cantilever walls are built of reinforced concrete, and require removal of some dump material. They are less tolerant of settlement.

To reduce and control hydrostatic pressures both types of walls must incorporate relief of subsurface drainage.

Drainage control diverts surface and subsurface water away from the dump. Flood water must not be allowed to traverse the top of fills. Any fills that cross drainages must provide for flow through the dump. This is normally accomplished through a rubble drain or french drain. As hydrologic conditions are a key factor in initiating instability, water control can reduce or eliminate problems associated with dump failures.

Surface water control involves reshaping dump surfaces and redirecting drainage channels away from the dump. Reshaping modifies the length, gradient, and shape of the dump slope. Long slopes must be broken up with terraces, benches, reverse benches, and drains or ditches that parallel the contours to divert surface runoff. (Also improves visual impact.) Maximum gradient should be 30° with a generally concave shape.

Subsurface drainage involves french drains made of nonerodable, nonslaking, permeable rock or perforated pipe that collects and removes groundwater. Drains must have sufficient capacity to transmit flood water safely though the base of the fill, typically the design criteria is a 100 yr flood event. They are placed in the bottom "V" of the fill surface. Where the fill is impermeable, the drains fan out onto the side slopes, and up into the fill.

COVER

If the material is toxic, it must be isolated as described under Reshaping Highwalls and Roads. If not, the dump must be revegetated which usually requires a source of soil and soil amendments as described under Revegetation.

Dumps also must be stabilized against blowing wind. Young vegetation will not survive wind blasting. For successful revegetation, dumps may require all or part of the following covering, from the bottom up:

* Where migration of salts or adverse chemicals is a problem, provide a capillary barrier (2 to 4 ft*) of coarse rock.

* A 12 in. layer of fine rock (10 to 12 in.*).

* Soil 24 to 48 in. thick.

REFERENCES: This section paraphrased from Thorne, 1987, p. 34; USFS, no date, p. 47 & 48; USOTA, 1986, p.63.

MINE DRAINAGE CONTROL

DESCRIPTION

While some drainage from mines is benign, frequently the drainage is highly acidic or alkaline and carries heavy metals. Polluted mine drainage forms by the percolation of water through material with soluble constituents. Polluted mine water often enters groundwater and nearby streams.

Acid mine drainage is most common and is characterized by low pH, and high concentrations of dissolved metals. The final products of the oxidation reaction are sulfuric acid and insoluble ferric hydroxide (yellowboy) precipitate. The acid may react with other minerals to yield compounds of aluminum, manganese, calcium, and others. Streams with high concentrations of these metals will not support desirable plant and animal life. Streams with a pH of 4 or below probably will be sterile except for acid tolerant bacteria and algae.

Mine water clean-up usually requires detailed investigation, analysis, process development, and engineering.

CONTROL TECHNIQUES

Mine drainage control techniques include mine sealing, land treatment, and water treatment.

<u>Sealing</u> involves placing (1) permanent bulkheads in mine openings, and (2) insitu grout curtains to cutoff flow of groundwater. Seals dam the flow of water from the mine so that the mine floods. This flooding creates an oxygen-deficient environment and prevents chemical reactions.

Advantages: Stops mine drainage and chemical reactions at source.

Disadvantages: Very difficult to implement. As bulkheads flood the mine, the water almost always finds another way out. Grout curtains are seldom completely effective in stopping flow of groundwater in or out of mine.

Cost: $10,000 to $500,000 per project.

<u>Land treatment</u> involves a number of techniques commonly used where surface water passes through mine waste dumps and becomes toxic. The techniques include surface water diversion, reprocessing dump material, and removal and burial. Refer to guidelines on backfilling (Reshaping Highwalls and Roads), and Waste Dump Mitigation.

Advantages: Very effective preventive measures.

Disadvantages: Generally applicable to only surface mines and surface facilities of underground mines.

Cost: $15,000 to $1,000,000 per project.

Neutralization is the most common treatment of acid mine drainage. Addition of lime or sodium hydroxide to the acidic water increases its pH. One problem is the instability of manganese. If there is substantial manganese in the water, the pH first must be raised to 10 or above. As the manganese precipitates out, the pH drops to acceptable levels. However, the manganese precipitate is easily resoluble at low pH, and must be removed.

Limestone barriers or limestone filled and perforated drums may be placed in low flow mine waters carrying mild acid drainage. This technique requires frequent maintenance.

Chemical oxidants, such as sodium hypochloride and potassium permanganate, are able to precipitate manganese while producing a relatively stable condition at near neutral pH. However, this method is more expensive than the excess alkalinity method.

Neutralization plants consist of multisequence processes in which tanks, bins, and other devices are used for chemical reactions.

Advantages: Currently the most effective means to treat mine drainage.

Disadvantages: High capital costs, continued operating and maintenance costs, and treatment must continue indefinitely.

Cost: $50,000 to $1,000,000 per project.

An environmental approach to treatment of acid mine drainage is wetlands. Wetlands have the capacity for removing metals. Practically, they are limited to small flows in that large areas are required.

The U.S. Bureau of Mines has a number of research projects underway on mine drainage problems. Contact the Assistant Director for Research for help.

REFERENCES: This section paraphrased from OSM, 1983, p. III-51 & III-58; Thorne, 1987, p. 32; USFS, no date, p. 27.

SUBSIDENCE MITIGATION

DESCRIPTION

Subsidence is the downward movement of the ground surface over an underground mine. See Fig. 18. For small areas of subsidence less than a few acres, use remediation measures described above for backfilling shafts.

For National Parks, most mining activities stopped long ago, subsidence has stabilized, and subsidence does not impact existing environmental resources or threaten public safety. Occasionally, subsidence results in steep drops, and to protect the public, the park should post warning signs and include warnings in park safety literature. In some cases, a park may want to control subsidence or backfill subsided areas to restore and protect natural resources.

> There are significant risks from the unknowing construction of park facilities on subsided ground. Minor settling can continue indefinitely, and can damage foundations and break utility lines. In addition, because subsidence progresses in a cone shape up and outward from the underground openings, neighboring mines can cause subsidence into park land.

Cost: $50,000 to $1,000,000 per project.

CONTROL TECHNIQUES

Subsidence control is accomplished through surface treatment, local foundation support, and deep subsurface reinforcement.

<u>Surface treatment</u> consists of restoring drainage, either by breaching the higher ground between the lower subsided areas and the natural down-gradient drainage system, or by raising the subsided area with backfill, as described under Reshaping Highwalls and Roads.

<u>Local foundation support</u> is added to structures susceptible to subsidence. This involves jacking existing buildings, reinforcing and broadening foundations, realigning utilities, installation of flexible or hinged couplings in utility lines, and installation of gas and subsidence detectors.

<u>Subsurface reinforcement</u> includes backfilling of mine voids or providing support to unstable geologic zones. Techniques used are hydraulic and pneumatic backfilling, and insitu grouting.

REFERENCE: This section paraphrased from OSM, 1983, p. III-32.

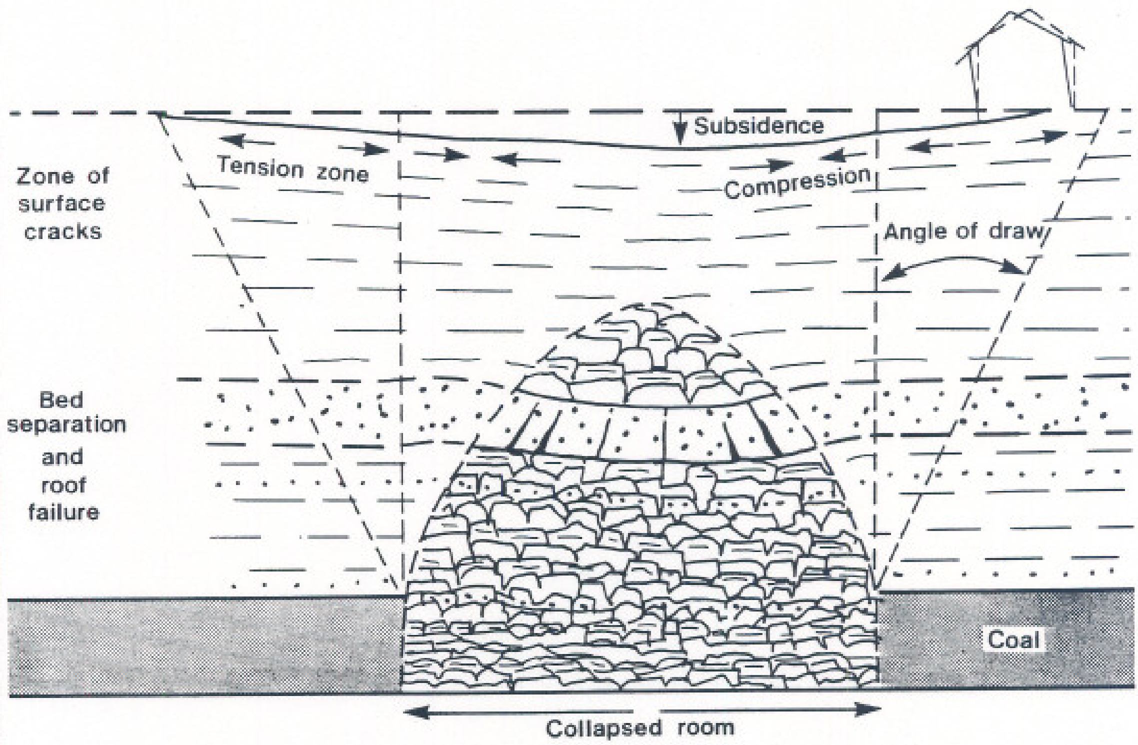


Figure 18. Mine Subsidence

MINE FIRES

DESCRIPTION

Mine fires occur in coal seams and coal waste dumps. At this time, there are no known mine fires in National Parks. However, a number of parks encompass past coal mining activities, and mine fires may be discovered or initiate in the future. If so, action must be taken quickly because fires are easier to extinguish early. In addition, mine fires can burn indefinitely causing significant air pollution and hazardous conditions.

CONTROL TECHNIQUES

The three general methods of controlling mine fires are excavation, sealing, flushing, and grouting. It is often necessary to combine these methods.

Excavation requires complete removal and cooling of all burning or heated material. After cooling, excavated material is backfilled, mixed with noncombustible material, and compacted to reduce oxygen. Primarily used with dumps.

Sealing involves blanketing the burning area with fine-grained inert material to seal all sources of air from the burning coal seam or waste dump. Prior to sealing, it is necessary to remove all vegetation. Sealing of waste dumps generally requires extensive site preparation -- steep slopes must be reduced, surface water runoff must be controlled, and burning material at the surface removed.

Flushing is usually associated with underground fires. Noncombustible solid materials are injected into seams through boreholes drilled from surface. The solids fill voids and seal air from the fire.

Grouting is associated with dump fires. A slurry is pumped into voids in the dump to retard or eliminate the flow of air.

REFERENCE: This section paraphrased from OSM, 1983, p. III-44.

STRUCTURES AND EQUIPMENT

DESCRIPTION

Abandoned structures and equipment are often hazardous to public safety. The structures tend to be weathered and unstable. When the decision has been make not to preserve the site, the facilities should be demolished and removed to a landfill.

Alternatively, temporary barriers should be erected to prevent access until permanent remediation is undertaken.

Cost: $3,000 to $100,000 per project.

CONSTRUCTION

Demolition

There are 4 methods of demolition, as follows:

Manual demolition requires simple hand tools, such as crowbars, sledgehammers, cutting torches, and saws. Most often used at sites where high salvage value exists, liability and risk of property damage is high, or heavy equipment access is limited.

Mechanical demolition, through use of wrecking cranes, jackhammers, and bulldozers, is less costly than manual demolition. Used where sufficient access and working area is available, and as required by structural strength, mass, and extent of structures.

Burning can be used at some sites where structures are combustible and there is no risk of igniting adjacent facilities and areas. Because water is usually not available at AML sites, fire must be easily confined and controlled with water tank trucks.

Blasting is primarily used to reduce concrete or masonry structures. Requires specialized expertise.

Resultant rubble and scrap is usually buried onsite and sometimes transported to landfills. Factors determining which option is best include site accessibility, type of construction, existence of convenient disposal areas onsite and offsite, difficulty of excavation, and availability of cover material. Other considerations are economic -- scrap value and transportation.

Barrier Construction

Barriers can be erected outside perimeter of the anticipated zone of collapse. Use NPS fencing specifications for barrier construction. In a few cases, where buildings are sound and will be used in future, barriers can be relatively simple seals blocking off entrances and windows.

REFERENCE: This section paraphrased from OSM, 1983, p. III-64.